An integrated hydrological study in the Yellow River Delta

Makoto Taniguchi (RIHN)

Introduction

Five field observations from 2003 to 2006 including intensive measurements on Sep., 2004, May 2005, and Sep. 2006, have been made in the Yellow River delta to evaluate (1) the effects of change in river water discharge on groundwater discharge and dissolved material transports into the Bohai Sea, (2) directions and magnitudes of water flow between Yellow River, groundwater, and Bohai Sea, and (3) hydrogeological features of the groundwater in the delta by uses of geophysical and geochemical methods from a long term perspective. The members of "Delta group" of the Yellow River Project (Leader: Prof. Y. Fukushima, RIHN)) are Makoto Taniguchi （RIHN）, Shin-ichi Onodera （Hiroshima Univ.）, Kunihide Miyaoka （Mie Univ.）, Jianyao CHEN（Sun Yat-sen Univ.）, Tomochika Tokunaga （Tokyo Univ.）, Tomotoshi Ishitobi （RIHN）, Mitsuyo Saito （Hiroshima Univ.）, Guanqun Liu （Ocean Univ. China）, William Burnett (Florida State Univ.), and Richard Peterson (Florida State Univ.).

Methods

The following four observations have been made during the study periods by "Delta group" members; (1) Observations of groundwater in the Yellow River delta, (2) Observations of the groundwater in the coastal zones, (3) Observations of the Yellow River, and (4) Observations at Estuary (Fig.1 and Fig.2).

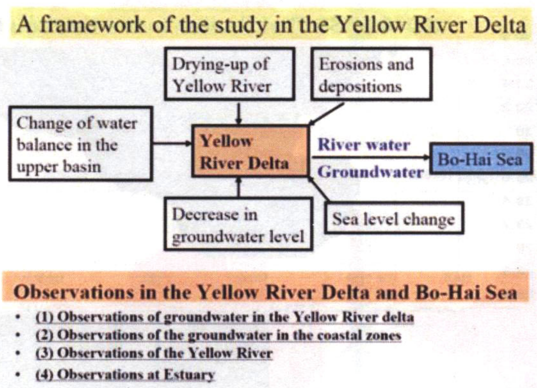


Fig.1 A framework of the study by delta group

	Bohai	(4)Estu.	(3) Y. R.	(2) GW in coast	(1) GW in Delta
May, 2003					GS
Jul., 2003					10 boreholes
Sep., 2003					GS, CTD, RT
Apr., 2004					CTD
Sep., 2004	Obs.	Obs.	Obs.	Seepage	RT, WQ
Dec., 2004			Obs.		
May., 2005	Obs.	Obs.	Obs.	Seepage	WQ
Jun., 2005			Obs.		
Sep., 2005					CTD
Dec., 2005					
Mar., 2006					CTD
Sep., 2006		Obs.		Seepage, TR	WQ
Jul. 2007	Obs,	Obs.	Obs.	Seepage	

Red : Japan Blue : China
GS:general survey, RT:resistivity, WQ:water quality, TR:thermo rader

Fig.2 Contents and periods of Delta G. observations

For the measurements of groundwater in the coastal zone by uses of seepage meters, six to seven automated seepage meters were used in each observation period in the field (Fig.3). Seepage meters, vented benthic chambers with some type of flux measurement device, are the only means available to evaluate Submarine Groundwater Discharge (SGD) fluxes directly. However, manual seepage meters using diver-deployed plastic bags as collectors, are very time and labor-intensive. We used the "continuous heat type" of automated seepage meters (Fig.4) to make the measurements in this study. Flux measurements are made by assessing a temperature gradient of water flowing between a downstream and upstream sensor in a tube with a heating element at one end. When there is no water flow, the temperature difference between sensors is highest and decreases systematically with increasing flow velocity. The chambers were made from the top or bottom sections of 55-gallon oil drums with a collection area of 0.255 m^2. Measurements of SGD at any one site were performed every 5 or 10 minutes.

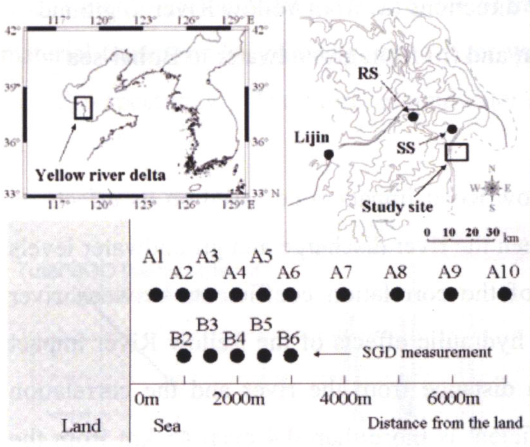


Fig.3 Locations of seepage meter

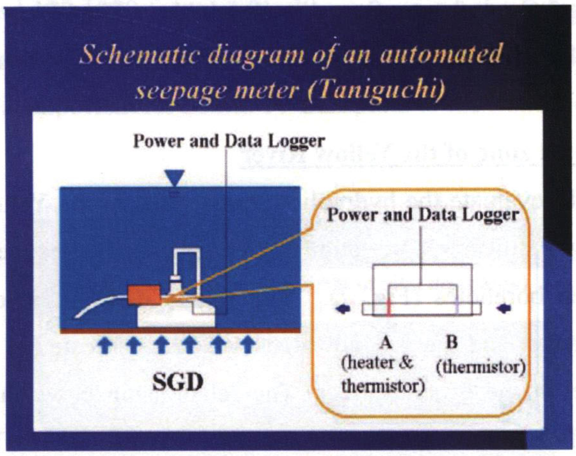
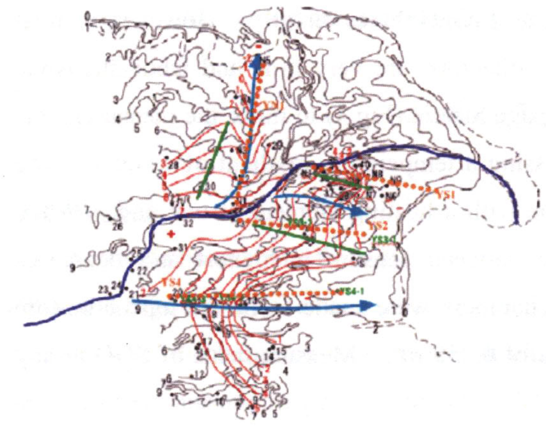


Fig.4 Schematic diagram of automated seepage meter

Characteristics of groundwater and water displacement in the delta

The Yellow River channel serves as the boundary of both surface and groundwater flow in the delta, and groundwater flows northeast wards in the north part and southeast wards in the south part of the study area. Contour of water table measured in September 2003 shows the flow directions of the groundwater in the delta (Fig. 5). Potential gradients of groundwater flow for the north and east direction based on the contour line in Fig. 5 was estimated to be 1/4500-1/4000 and 1/7000 respectively. Pumping test for the ten new wells gave a transmissivity of 0.036-0.61 m^2/d. The general flow directions between surface water- groundwater –seawater are shown in Fig. 6 based on the measurements of groundwater potential and electric conductivity on Sep. 2003. As can be seen from Fig. 6, water movements occurred from the Yellow River to surrounding groundwater (Fig.6a) and groundwater to the Bohai sea (Fig.6b).



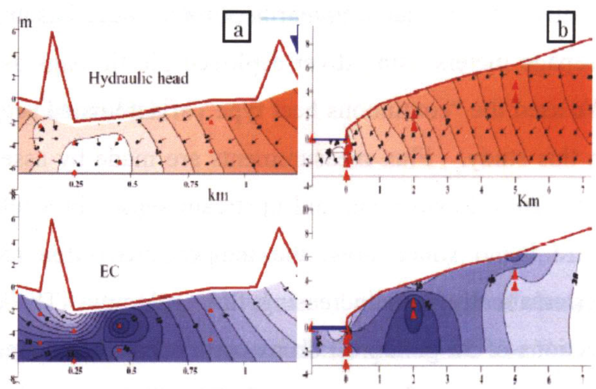
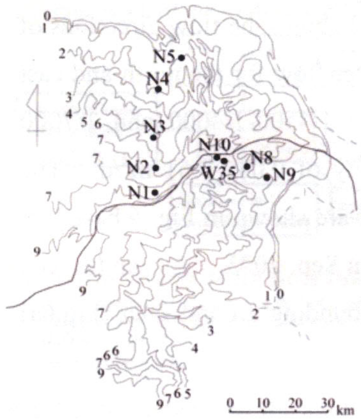


Fig.5 Groundwater flow direction in the Yellow River delta

Fig.6 Flow directions (a) from Yellow River to groundwater, and (b) from groundwater to Bohai-sea

Impact zone of the Yellow River

To evaluate the hydraulics connections of the Yellow River impact zone based on its effects on the groundwater, correlation analyses were made between the river discharge and groundwater levels at ten boreholes (Fig. 7). The spatial distribution of the correlation coefficients between river discharge and the groundwater level may indicate the hydraulic effects of the Yellow River impact zone on the groundwater. The relationship between distance from the river and the correlation coefficient is shown in Fig. 8. The correlation coefficient is more than 0.4 even 45 km from the Yellow River in the northern area of the delta; however, it decreases dramatically to 0.18 in the southern area, which adjoins the Bohai Sea. The groundwater is connected-to seawater next to the coastal zone, and therefore, the correlation between river water and groundwater was weaker. However, the hydraulic connection between river water and groundwater was observed over 45 km from the Yellow River because of water loss to the groundwater.



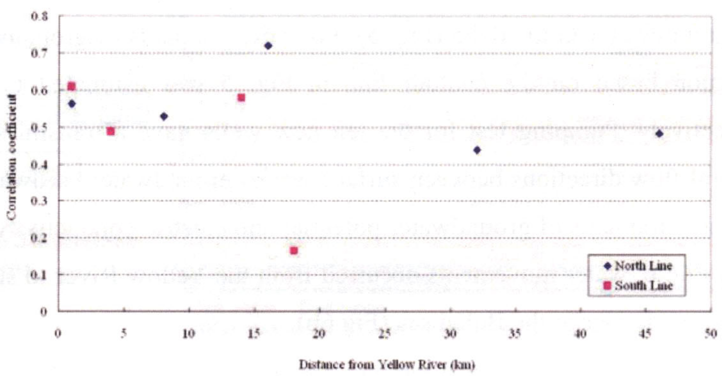


Fig. 7 Locations of boreholes

Fig.8 Correlation coefficients between river discharge and groundwater level in the delta.

Water and nutrient transports into the Bohai sea by river and groundwater

According to the integrated SGD and SFGD from the coast to 2500 m offshore on Sep 2004, the total SGD is the same order of river discharge (Fig.9). On the other hand, SFGD (Submarine Fresh Groundwater Discharge) which is separated from SGD by uses of CT (conductivity and temperature) sensor in the camber of the seepage meter, the ratio of SFGD to SGD was about 3-8 % of the river discharge. Assuming the coastal line of the delta to be 150 km, the fresh groundwater discharge from the whole delta was estimated to be 10 million ton per year

Material transports by river and groundwater depends of flow rate and concentrations of each material. Assuming 5 % for the ratio of SFGD to river discharge, and ratios of concentrations of river water to groundwater (100:1190 for Si and 100:1000 for total P), then we can get the ratios of material transports by groundwater to river water. Those ratios are 100:60 and 100:50 for Si and total P, respectively. Therefore, groundwater is important for Si and TP transports to the Bohai sea

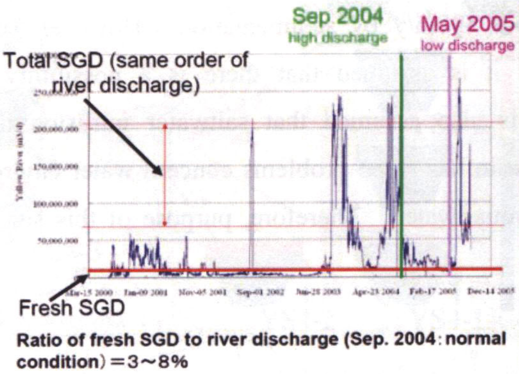


Fig.9 Changes of the Yellow river discharge and The ranges of SGD and SFGD

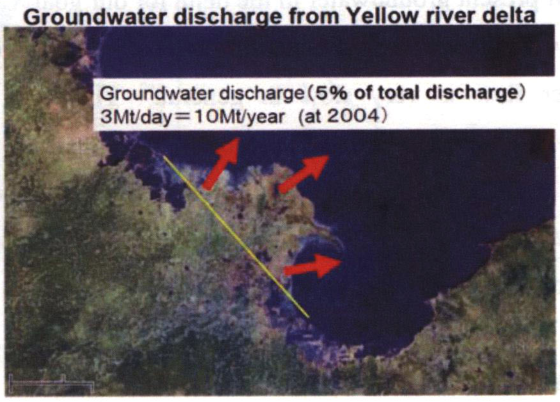


Fig. 10 Fresh groundwater discharge from the Yellow River delta

Conclusions

The results are summarized as follows; (1) groundwater discharge from the Yellow river delta to the Bohai sea was estimated to be 5 % of the river discharge during the high river discharge period, and will be increased during low flow period, (2) an importance of phosphate and silica transports by groundwater into the Bohai sea was recognized, (3) A new concept of "impact zone" is defined for the lower reach of the Yellow River basin, as a transboundary issue instead of river basin. There is still a data gap in the coastal area on nutrient discharge, therefore, one more field measurement is necessary.